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Assessment of the 4VWX Silver Hake Population in 1995

by

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Management and Current Fishery

The silver hake fishery on the Scotian Shelf has traditionally been pursued by large (TC 7) vessels of the distant waters fleets of Russia, Cuba, and Japan. Prior to 1977, fishing on the Scotian Shelf was unrestricted in terms of area, mesh size, and season. During this period fishing occurred over the entire shelf, and the use of trawl mesh as small as 40 mm was common. In 1977, Canada implemented the Coastal Fisheries Protection Act, which restricted fishing for this species to the seaward side of the Small Mesh Gear Line (Figure 1), west of 60° W longitude, with a minimum mesh size of 60 mm. On an experimental basis a portion (4-6 vessels) of the fleet was allowed to fish inside the line during 1978 and 1979. From 1980 through 1983 fishing was permitted by condition of licence in an eastern extension of the box as far as 57° W longitude; from 1984 to present this eastern extension has been restricted to 59° W longitude.

By regulation the fishery opens April 1 and closes November 15 each year; however, in recent years vessels have been allowed to commence fishing under experimental permit in March.

Canadian fishing interests have been active in the harvesting of this species since 1990. However, the long distance to the primary fishing area and deep water preferred by silver hake have caused difficulty for the smaller Canadian vessels. In 1995 several Canadian vessels were permitted to fish for silver hake in and around Emerald and LaHave basins, which are much closer to processing facilities than the area outside the small mesh gear line. Fishing was generally successful, and resulted in a Canadian catch of 300 tons. However, as was the case in previous years, most of the harvesting under Canadian allocations in 1995 was through charter arrangements with Cuban fishing companies. As a result, although allocations of silver hake to foreign nations have been substantially reduced, the overall vessel and gear composition of the fleet harvesting the majority of this stock has remained the same.

As was the case in 1994, management measures were implemented to minimize incidental catches of cod, haddock and pollock in the silver hake fishery; the silver hake box was modified to prevent fishing in depths of less than 190 m (Figure 1) and use of a separator grate in the lengthening piece of the trawl was mandatory. However, as was the case in 1994, Cuban fishing vessels were granted exemptions to fish inside the new line late in the fishing season.

Nominal catches from this stock have ranged from 300,000 tons in 1973 to 8,000 tons in 1994. The provisional catch in 1995 was 18,000 tons, of 50,000 tons allocated. This is more than twice that caught in 1994, but still the second lowest catch in the time series 1970-95 (Table 1). The NAFO Scientific advice (tons) on catch levels, Total Allowable Catches (TAC's)

established, and total catches from 1985 are as follows:

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Advice	100	100	100	167	235		100	105	75	51 (40[3])	79 (59[4])	64
TAC	100	100	100	120	135	135	100	105	86[2]	30	50	60
Catch	75	83	62	74	91	69	68[1]	32[1]	29[1]	8[1]	18[1]	-

[1] Preliminary
[2] Includes additional 11,000 tons allocated by Canada in the expectation that not all allocations would be harvested.
[3] Adjustment for retrospective; see Special comments, NAFO Sci. Counc. Rep., 1993.
[4] Adjustment for retrospective; see Special comments, NAFO Sci. Counc. Rep., 1994.

Removals and Weights at Age

Sampling for length composition and otoliths in the 1995 commercial catch was conducted by Canadian observers. More than 1,800 samples (206,928 lengths; 1,347 otolith pairs) were collected during 1995. A summary of length and age sampling is presented in Table 2.

The commercial removals at age for 1995 were calculated using the same procedure as the previous assessment, using Canadian length frequency data and monthly age/length keys constructed from Canadian aging data. Regressions of lengths and weights from the Canadian July research vessel survey were used to calculate yearly alpha and beta values (Table 3) used in the calculation of sample weights and weight-at-age. As was the case in 1994, Russia did not participate in the 1995 fishery, and hence no commercial sampling or age data were available from this source. The removals at age and weight-at-age for 1977-1994 were taken from the previous assessment (Showell and Bourbonnais, 1995) to provide estimates for the period 1977-95 inclusive (Table 4 & 5).

As was noted in the previous assessment, commercial mean weight-at-age has shown a declining trend since 1992, and research vessel mean weight-at-age exhibited similar tendencies (Hunt, 1995). In the 1995 fishery this decline has stopped, with mean weight at ages 1-6 either remaining the same or increasing slightly (Figure 2). Weight-at-age data from the Canadian July survey show a similar pattern (Figure 3) where most age groups increase slightly in weight in 1995.

Commercial Catch Rates

In the 1990 to 1994 assessments of 4VWX silver hake a multiplicative model using the APL workspace STANDARD was used to standardize catch rates. In the 1995 assessment discussion focussed on the possibility that interaction effects might be influencing the results of the catch rate standardization, based on work by Myers *et al.* (1995). A more rigorous examination of the catch rate data showed problems in the STANDARD assumption of log-normal distribution of the data, and the pattern of residuals indicated non-homogeneous variance (Smith & Showell, 1996). In addition, changes in the analysis of variance results with changes in the order of introduction of the main effect terms suggested aliasing was occurring between main effects.

Smith & Showell (1995) found a gamma distribution fit the data better than a log-normal distribution. The data were subsequently analyzed using this gamma distribution in an analysis of deviance using an all subset model. Results suggest country, month and area are not significant, and that a model with year alone has as much explanatory power as one which includes all four factors. Based on this analysis, a non-standardized catch rate series using Canadian observer data was calculated using catch rates (Table 6, Figure 4). The catch rates for this stock have dropped from high levels in the period 1984-89, to relatively low levels in 1992 though 1995.

Canadian Bottom Trawl Surveys

The July stratified random groundfish survey has been conducted on the Scotian Shelf from 1970 using three Canadian research vessels (*A.T. Cameron*, *Lady Hammond*, and the *Alfred*

Needler). A conversion factor of 2.3 is applied to the series prior to 1982 to account for the effect of vessel and gear changes between the *A.T. Cameron* and the other two vessels (Fanning, 1985). No conversion factor is required between the *Lady Hammond* and the *Alfred Needler*.

Survey trends in both total numbers and biomass show relatively high abundance in the early to mid 80's, followed by a decline to relatively low levels over the period 1988-94 (Figure 4). Results of the 1995 survey indicate a modest increase in both numbers and biomass over those seen in the previous six years.

In numbers at age (Table 7) the 1994 and 1992 year classes appear to be above average in size at age 1 and 3 respectively, while the 1993 year class is average at age 2.

Juvenile Survey

A standardized IYGPT O-group survey for this species has been conducted since 1981 (1992 excluded) during the October-November period. Analysis of the 1995 survey produced a stratified mean number per tow of 252.0 This point is the third highest in the time series, and suggests the possibility of a strong 1995 year class. These data, as well as those of previous years for the core strata (60-78) are presented in Table 8.

Estimation of Parameters

Sequential Population Analysis

The sequential population analysis was calibrated by means of the adaptive framework, ADAPT (Gavaris, 1993) using the Canadian July R/V survey (1979-95), age disaggregated CPUE (1979-95), and the O-group survey (1983-1995) as tuning indices. The formulation included a catch at age from 1979 to 1995, ages 1 to 9, fully recruited ages 3, 4 and 5, natural mortality of 0.4, and a dome shaped recruitment pattern, with F at age 9 set at 10% of fully recruited. Results of this analysis are shown in Table 9a,b, & c. In the past (Showell and Bourbonnais, 1994) the analytical assessment of this resource has shown changes with the addition of additional data, with a tendency for the current estimate of population size to be optimistic. As a result, an analysis for a retrospective pattern was conducted (Figure 6). While not as severe as seen in the past, F for the fully recruited age groups was underestimated by approximately 50% in some years. The retrospective pattern was also analyzed in terms of numbers, on an age-by-age basis (Figure 7, Table 13). Age 1 numbers were found to be quite variable, with no pattern in time, and ranged from a large underestimate in 1992 to a large overestimate in 1993. Trends for older ages were more consistent, with the degree of overestimation on average increasing with age.

Beginning of the year population numbers, biomass, and fishing mortality at age are shown in Table 10. In 1995 the estimated average F over ages 3-5 was low, at approximately 0.2.

Recruiting Yearclass Sizes

The estimates of the 1993 and earlier yearclasses can be accepted from the SPA; however, the strength of the 1994 and 1995 yearclasses must be inferred from research vessel data.

The 1995 yearclass will make a significant contribution to the catch in 1997 at age 2. The only available data to estimate the size of this age class is the O-group survey. The index from this survey was regressed against age 1 numbers from the SPA for the same year class (1983-91 yearclasses). The regression was significant, with an R^2 of 0.52 (Table 11). The predicted size of the 1995 year class from this relationship is relatively large at 1.28 billion fish.

The 1994 yearclass will be fully recruited at age 3 in 1997, but cannot be reliably estimated in the SPA. The strength of the 1994 yearclass was estimated from both the July survey data and the O-group survey. Yearclass estimates from the survey at age 1 were regressed against estimates from the SPA for the 1982-1992 yearclasses, using the model SPA=a + b(lnRV); R^2=0.49 (Table 12). Data for yearclasses prior to 1982 were excluded due to questions of comparability between research vessels. The prediction from this relationship for the strength of the 1994 yearclass was 1,100 million fish, while the estimate from the O-group survey was 720 million. Since the amount of variation explained by the two relationships was approximately the same, the size of the 1994 yearclass was taken as an average of the two estimates, at 910 million fish.

Projection

An $F_{0.1}$ value of 0.70 was used, based on the yield-per-recruit analysis conducted in the 1994 assessment. As the commercial mean weights-at-age have declined sharply since 1992, and have stabilized at lower levels in 1995. As this drop appears to be a biological phenomenon rather than a result of sampling or ageing biases, mean weights-at-age for projection were taken as the average of the period 1991-95. Due to the retrospective pattern where numbers from the SPA were overestimated, these numbers were adjusted, on an age-by-age basis, for catch projection purposes. Weight at age, numbers, and partial recruitment were:

age	Avg weight (kg)	PR	numbers[1]
1	0.057	0.02	910,000
2	0.103	0.25	381,011
3	0.140	0.73	320,731
4	0.177	1.00	107,890
5	0.210	0.75	37,411
6	0.287	0.66	6,829
7	0.390	0.44	1,194
8	0.393	0.54	331
9	0.766	0.08	156

[1]Jan1, 1995 numbers, age 2+ adjusted for retrospective pattern

The 1996 silver hake fishery is still in progress, and the exact total catch cannot be determined at this time. Based on preliminary catch rates, level of participation, and historical trends in resource availability, the final catch was predicted to be similar to that of 1995, at 18,000 tons. The catch at a target fishing level of $F_{0.1}$ is estimated to be 49,000 tons (Table 14).

References

Fanning, L.P 1985. Intercalibration of research survey results obtained by different vessels. CAFSAC Res. Doc. 85-3. 43p.

Gavaris, S. 1993. Analytical estimates of reliability for the projected yield from commercial fisheries. p 185-191. In: S.J. Smith, J.J. Hunt, and D. Rivard (ed). Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Aquat. Sci. 120.

Hunt, J.J. 1995. Evaluation of changes in weight at age and growth rate for 4VWX silver hake, 1983-94. NAFO SCR. Doc. 95/44 N2554. 12pp.

Myers, R.A., W.R. Bowering, and D. Power 1995. An analysis of catch per unit effort for Greenland halibut off Newfoundland. NAFO Scr. Doc. 95/65 N2580 8p.

Showell, M.A. and M.C. Bourbonnais 1994. Status of the Scotian Shelf silver hake populations in 1993, with projections to 1995. NAFO Scr. Doc. 94/32. 33p.

Showell, M.A. and M.C. Bourbonnais 1995. Assessment of the 4VWX silver hake population in 1994. NAFO Scr. Doc. 95/76 22p.

Smith, S.J. and M.A. Showell 1996. Analysis of catch-per-unit effort data for Scotian Shelf silver hake. NAFO Scr. Doc. 96/xx 10pp.

Table 1. Nominal catches for 4VWX silver hake 1970-1994 (1992-1994 preliminary).

Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Bulgaria	0	0	0	0	0	1722	3088	862	606	4639	817	0	0
Canada	0	0	0	0	11	101	26	10	26	13	104	6	38
Cuba	0	0	201	0	0	1724	12572	1847	3436	1798	2287	642	11969
France	0	0	0	0	0	0	0	15	0	0	0	0	2[1]
FRG	0	0	10	0	296	106	97	684	0	0	0	0	0
GDR	0	0	0	0	0	0	0	0	3	0	0	0	0
Ireland	0	0	0	0	0	108	106	0	0	9	0	0	0
Italy	0	0	0	0	0	0	0	38	106	5	0	541	37[1]
Japan	129	8	63	88	67	54	78	19	161	219	239	120	937
Poland	0	0	0	0	0	0	0	295	2	0	0	1[1]	31[2]
Portugal	0	0	0	0	0	0	0	0	0	0	56	2044	2[1]
Romania	0	0	0	0	0	0	0	10	0	1	0	0	0
Spain	0	15	0	0	0	6	0	0	2	0	40	0	0
USA	0	1	1	1	1	7	1	14	0	0	0	3	2
USSR	168916	128633	113774	298533	95371	112566	81216	33301	44062	45076	40982	41243	47261
Total	169045	128657	114048	298621	95745	116394	97184	37095	48404	51760	44525	44600	60251

Country	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Bulgaria	0	0	0	0	0	0	0	88	0	0	0	0	0
Canada	15	10	2	9	13	9	337	10	34	4[1]	73[1]	57[1]	300[1]
Cuba	7418	14496	17683	16041	20219	9016	14541	13888	23708	16528[1]	22018[1]	7788[1]	16835[1]
France	0	0	0	0	0	0	0	0	0	0	0	0	0
FRG	0	0	0	0	0	0	0	0	0	0	0	0	0
GDR	0	93	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	2[2]	0	0	0	0	0	0	0	0	0	0	0	0
Japan	649	530	120	66	144	0	194	315	781	547[1]	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	378	1714	1338	0	0	0	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0
USA	0	0	0	1	0	0		0	0	0	0	0	0
USSR	27377	57423	56337	66571	41329	65349	72917	55429	40786	14716[1]	7139[1]	0	0
Total	35839	74266	75480	82688	61705	74374	87989	69730	65309	31795	29230	7845	17835

[1] Observer Program Data (data not reported to NAFO)
[2] FLASH data

Table 2. Commercial sampling of 4VWX silver hake, 1977-1995.

Year	No. Lengths	No. Ages
1977	34379	600
1978	137468	674
1979	101908	1108
1980	247369	1462
1981	195493	987
1982	160878	1152
1983	134226	986
1984	203314	1255
1985	216912	1163
1986	197654	1311
1987	377527	681
1988	309767	1158
1989	300100	1135
1990	447587	1817
1991	556765	1712
1992	336562	1721
1993	350440	1563
1994	138199	914
1995	206928	1347

Table 3: Length/weight regressions: Male and female alpha and beta's used in the construction of the silver hake catch at age used in this assessment. Lengths (cm) and weights (kg) used were from the Canadian July Research Vessel Survey of the Scotian Shelf (4VWX).

Year	Male - Alpha	Female - Alpha	Male - Beta	Female - Beta
1977	0.000006260	0.000006930	3.0626	3.0350
1978	0.000004630	0.000003070	3.1366	3.2531
1979	0.000010200	0.000005880	2.9001	3.0675
1980	0.000002330	0.000001800	3.3417	3.3989
1981	0.000006830	0.000005080	3.0206	3.1172
1982	0.000011600	0.000006740	2.8575	3.0232
1983	0.000006480	0.000003320	2.9935	3.2034
1984	0.000018300	0.000006490	2.7052	3.0284
1985	0.000013500	0.000004530	2.7848	3.1235
1986	0.000007970	0.000003820	2.9384	3.1685
1987	0.000009990	0.000004240	2.8798	3.1456
1988	0.000014300	0.000004800	2.7942	3.1241
1989	0.000006750	0.000004440	3.0114	3.1416
1990	0.000034320	0.000021000	2.5234	2.6958
1991	0.000007773	0.000003488	2.9582	3.2036
1992	0.000003938	0.000003157	3.1824	3.2533
1993	0.000003461	0.000003089	3.178	3.2202
1994	0.000003336	0.000003147	3.2009	3.2228
1995	0.000003340	0.000002367	3.2151	3.3233

Table 4: Commercial catch numbers at age for 4VWX silver hake.

Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	17911	20940	20569	16588	2358	20189	5849	59588	14970	45598
2	72529	70302	57893	70696	25214	52976	96852	45828	130814	70269
3	59862	80196	72891	70391	109035	75876	56158	206900	98346	229126
4	15070	35025	36669	32032	37573	68400	29282	82911	128365	84097
5	2218	12709	22380	14465	11928	31752	11388	19344	34110	28635
6	725	5227	9970	5184	3234	5945	3395	4268	9327	8760
7	97	1906	3168	1431	1201	2042	819	1038	2344	1436
8	91	1168	495	451	290	465	253	183	226	497
9	4	338	374	98	141	64	88	10	85	111

Age	1987	1988	1989	1990	1991	1992	1993	1994	1995	
1	6804	5110	24264	6516	5738	7461	31572	1651	3498	
2	214235	62791	85846	209620	117305	76663	83140	13265	35925	
3	114417	265307	158745	142862	201243	73526	70735	35250	45615	
4	54211	39242	145105	41215	46414	27777	35222	8847	31316	
5	13063	21303	20025	11741	12154	3461	5511	1283	5183	
6	6045	3106	9369	1648	3954	1247	595	150	457	
7	347	2133	1569	640	290	159	71	18	58	
8	156	208	1166	107	181	33	30	8	41	
9	117	143	39	40	50	5	3	0	3	

Table 5: Silver hake commercial mean weights at age.

Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.065	0.074	0.076	0.04	0.061	0.066	0.067	0.07	0.068	0.053
2	0.183	0.153	0.178	0.151	0.168	0.169	0.128	0.146	0.136	0.145
3	0.264	0.229	0.227	0.223	0.215	0.231	0.196	0.181	0.177	0.184
4	0.34	0.266	0.274	0.287	0.276	0.275	0.239	0.224	0.21	0.25
5	0.446	0.335	0.304	0.341	0.326	0.317	0.289	0.272	0.244	0.25
6	0.632	0.405	0.389	0.391	0.401	0.394	0.365	0.353	0.295	0.274
7	0.886	0.438	0.455	0.531	0.553	0.446	0.395	0.405	0.41	0.392
8	0.922	0.54	0.838	0.839	0.923	0.513	0.457	0.624	0.582	0.514
9	2.12	0.892	0.838	0.859	1.137	0.506	0.444	0.65	0.669	0.644

Age	1987	1988	1989	1990	1991	1992	1993	1994	1995	
1	0.045	0.045	0.06	0.063	0.047	0.08	0.06	0.050	0.060	
2	0.119	0.139	0.135	0.139	0.139	0.14	0.11	0.100	0.100	
3	0.168	0.185	0.195	0.184	0.189	0.19	0.15	0.130	0.140	
4	0.211	0.227	0.224	0.217	0.215	0.21	0.19	0.170	0.170	
5	0.248	0.26	0.278	0.24	0.263	0.26	0.23	0.190	0.210	
6	0.286	0.292	0.349	0.315	0.471	0.28	0.28	0.270	0.310	
7	0.453	0.401	0.403	0.37	0.471	0.37	0.38	0.380	0.410	
8	0.422	0.497	0.511	0.401	0.511	0.41	0.32	0.420	0.440	
9	0.518	0.688	0.82	0.545	0.568	0.69	0.96	0.717	0.620	

Table 6: Catch rates (non-standardized) from the 4VWX silver hake fishery, from Canadian observer data 1979-95

year	CPUE
1979	1.71
1980	2.04
1981	1.71
1982	3.20
1983	1.76
1984	2.94
1985	2.82
1986	3.48
1987	2.75
1988	2.80
1989	3.89
1990	1.89
1991	1.70
1992	1.32
1993	1.43
1994	1.36
1995	1.34

Table 7: Scotian Shelf silver hake Canadian July research vessel survey catch numbers ('000) at age.

Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	7737	26740	89437	17730	32839	192025	114273	188970	102726	552598
2	27660	23257	152705	55638	84724	293420	108957	70369	172576	84325
3	21421	16266	67003	97253	131420	80348	38209	208723	34402	70625
4	4592	8874	20048	45862	60469	60487	19340	37926	71191	22623
5	1348	6733	11522	10684	16241	32426	10632	11828	21488	13448
6	1278	3046	5055	4525	5127	8257	2882	7942	9445	4235
7	984	1286	2664	2001	2367	3549	876	2860	2667	1622
8	336	502	969	589	794	2535	401	1136	1175	673
9	283	865	275	385	564	327	337	522	215	376
1+	65639	87569	349678	234667	334545	673374	295907	530276	415885	750525
Age	1987	1988	1989	1990	1991	1992	1993	1994	1995	
1	146007	69740	172095	117089	66678	45284	166402	78069	182963	
2	266663	89508	63810	125952	84743	56347	91306	59547	53740	
3	46095	81458	24151	42329	35293	46180	74838	37734	80899	
4	18982	16709	13405	13022	13257	11097	25736	15082	49309	
5	6048	14249	4130	4173	6577	4477	3296	6734	14467	
6	4168	2502	1868	1169	2456	2237	805	1173	3325	
7	1199	2338	769	432	402	424	524	305	1609	
8	672	468	282	227	143	139	98	204	531	
9	471	121	129	82	124	192	38	131	362	
1+	490305	277093	280639	304475	209904	168890	363061	199067	387205	

Table 8: Stratified mean catch per tow for the Canada-Russia juvenile silver hake survey, core strata (60-78).

Year Class	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992[1]	1993	1994	1995
mean catch/tow	579.0	8.8	232.2	43.4	284.8	198.0	102.0	204.8	131.5	187.4	78.6	-	186.5	105.4	252.0
std.error	64.4	1.2	24.4	7.1	62.2	37.9	23.0	35.3	19.0	24.1	10.4	-	17.2	8.4	60.5
CV	0.11	0.14	0.11	0.16	0.22	0.19	0.23	0.17	0.14	0.13	0.13	-	0.09	0.08	0.24
number of sets	77	61	64	71	82	74	105	79	74	68	71	-	95	73	83
July RV age 1 #'s (10^6)	192	114	189	103	553	146	70	172	117	67	45	166	78	183	-

[1] no survey in 1992.

Table 9a: Parameter estimates from ADAPT for 4VWX silver hake using Canadian July RV survey (ages 1-9), commercial CPUE (ages 1-9) and O-group index (age 1).

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.003483
MEAN SQUARE RESIDUALS 0.509962

PARAMETER	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
age 2	1.352E1	4.285E-1	3.169E-2	2.485E-3	1.838E-4
age 3	1.253E1	3.584E-1	2.861E-2	-2.039E-3	-1.627E-4
age 4	1.224E1	3.515E-1	2.872E-2	-5.598E-3	-4.575E-4
age 5	1.114E1	3.160E-1	2.835E-2	2.145E-3	1.924E-4
age 6	1.036E1	3.180E-1	3.070E-2	4.678E-4	4.517E-5
age 7	8.796E0	3.332E-1	3.789E-2	5.532E-4	6.289E-5
age 8	7.065E0	3.349E-1	4.740E-2	-2.898E-3	-4.102E-4
age 9	5.709E0	3.390E-1	5.938E-2	-9.768E-3	-1.711E-3
RV age 1	-1.115E1	1.777E-1	-1.593E-2	-2.572E-3	2.306E-4
RV age 2	-1.068E1	1.759E-1	-1.647E-2	-2.267E-3	2.122E-4
RV age 3	-1.035E1	1.752E-1	-1.693E-2	-2.133E-3	2.061E-4
RV age 4	-1.005E1	1.751E-1	-1.743E-2	-2.140E-3	2.130E-4
RV age 5	-9.757E0	1.758E-1	-1.802E-2	-1.296E-3	1.328E-4
RV age 6	-9.540E0	1.765E-1	-1.850E-2	8.353E-5	-8.756E-6
RV age 7	-9.451E0	1.764E-1	-1.867E-2	1.275E-3	-1.349E-4
RV age 8	-9.611E0	1.760E-1	-1.831E-2	2.228E-3	-2.319E-4
RV age 9	-9.883E0	1.750E-1	-1.770E-2	2.474E-3	-2.503E-4
CPUE 1	-1.426E1	1.777E-1	-1.246E-2	-2.572E-3	1.804E-4
CPUE 2	-1.182E1	1.759E-1	-1.489E-2	-2.267E-3	1.918E-4
CPUE 3	-1.062E1	1.752E-1	-1.650E-2	-2.133E-3	2.008E-4
CPUE 4	-1.026E1	1.751E-1	-1.707E-2	-2.140E-3	2.087E-4
CPUE 5	-1.029E1	1.758E-1	-1.708E-2	-1.296E-3	1.259E-4
CPUE 6	-1.043E1	1.765E-1	-1.692E-2	8.353E-5	-8.010E-6
CPUE 7	-1.097E1	1.764E-1	-1.608E-2	1.275E-3	-1.162E-4
CPUE 8	-1.144E1	1.760E-1	-1.538E-2	2.228E-3	-1.947E-4
CPUE 9	-1.266E1	1.750E-1	-1.382E-2	2.474E-3	-1.954E-4
Juv 1	-8.810E0	2.032E-1	-2.307E-2	-2.989E-3	3.392E-4

Table 9b: Results of bias adjustment for population estimates.

PARAMETER	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
age 2	744184	318887	0.43	70162	0.09
age 3	276290	99041	0.36	17186	0.06
age 4	206280	72505	0.35	11586	0.06
age 5	69190	21866	0.32	3603	0.05
age 6	31478	10010	0.32	1606	0.05
age 7	6606	2201	0.33	370	0.06
age 8	1170	392	0.33	62	0.05
age 9	302	102	0.34	14	0.05
age 10	148	27	0.18	0	0.00

RV

	1	2	3	4	5	6	7	8	9
1979	-0.16086	0.62856	0.41358	-0.11259	-0.44752	-0.19509	-0.87320	-0.62118	-2.13870
1980	-1.46200	-0.61469	0.51441	0.67464	0.12085	-0.64629	-0.00688	-1.57920	-0.75084
1981	-1.12480	0.08333	0.63232	0.55570	0.31131	0.27215	-0.67286	0.02142	-0.87147
1982	0.07359	1.05470	0.34151	0.62851	0.88742	0.50001	1.12690	0.12523	-0.02219
1983	0.18533	-0.49450	-0.74813	-0.60004	-0.35979	-0.47809	-0.88065	0.44871	-1.13020
1984	0.21047	-0.31200	0.55008	-0.16716	-0.54018	-0.08404	0.26001	0.15107	1.72880
1985	0.18754	0.17896	-0.68123	0.35018	0.33510	0.03408	-0.48303	0.18840	-0.73114
1986	0.97820	0.02874	-0.10777	-0.16015	-0.24690	0.35850	-0.93240	-1.00260	-0.13700
1987	0.46569	0.31893	-0.05211	-0.54258	-0.33369	-0.47453	0.46761	-1.09280	-0.56186
1988	-0.22233	-0.01069	-0.31224	-0.22405	0.04909	-0.29407	-0.12776	0.50326	-2.07140
1989	0.31443	-0.26095	-0.68233	-0.73355	-0.17349	-0.40503	-0.30236	-0.82769	0.22026
1990	0.45868	0.16389	0.02267	-0.18482	-0.33768	0.33548	-0.10405	-0.30569	-0.78233
1991	-0.09511	0.27434	-0.10287	0.38429	0.56756	1.09890	0.77091	0.42127	-0.02473
1992	-0.62086	-0.20759	0.25286	0.11178	0.77430	0.96030	1.50090	1.04790	2.02230
1993	0.51493	0.13323	0.50865	0.56612	0.02002	-0.06392	0.38223	1.71710	0.68311
1994	-0.02474	-0.54650	-0.47381	-0.68645	-0.13369	-0.33738	-0.46741	0.09063	3.20850
1995	0.32183	-0.41773	-0.07560	0.14018	-0.49273	-0.58099	0.34205	0.71414	1.35890

CPUE

	1	2	3	4	5	6	7	8	9
1979	0.38377	-0.29208	-0.31408	-0.38581	-0.33485	0.28653	-0.26313	-0.54664	-0.14064
1980	0.30227	-0.50944	-0.80427	-0.74484	-0.31095	-0.89146	-0.08891	-1.28350	-0.61210
1981	-1.74850	-1.08370	-0.37059	-0.80146	-0.55287	-0.39052	-0.91881	-0.24385	-0.57143
1982	0.39432	-0.04901	0.03119	0.43327	0.87401	0.53275	1.56980	-0.26559	0.59620
1983	-0.38744	-0.17783	-0.78975	-0.67709	-0.45717	-0.12669	-0.12595	1.11960	-0.39718
1984	1.18920	-0.57306	-0.15205	-0.14352	-0.48097	-0.78411	-0.19817	-0.80993	-0.41600
1985	0.34470	0.01997	-0.37395	0.13147	0.31475	-0.10728	-0.10652	-0.64499	0.10032
1986	0.95154	0.34939	0.71096	0.72956	0.41138	1.34150	-0.16366	-0.10577	0.78728
1987	0.05369	0.78906	0.68492	0.26957	0.52489	0.33946	0.30427	-1.16710	0.37584
1988	-0.80859	-0.30299	0.06961	-0.23433	-0.08705	-0.26247	0.23021	0.45155	-0.20078
1989	0.65990	0.37511	0.67890	1.06140	1.14410	1.30010	1.13770	1.62810	1.00480
1990	-0.58365	0.55452	0.25915	-0.07772	-0.02252	0.31326	0.55775	-0.47968	0.02242
1991	-0.79900	0.38326	0.56056	0.49484	0.36489	1.11200	0.61567	1.13770	0.49226
1992	-0.16199	0.36858	0.15382	0.40005	0.21341	0.42608	1.20460	0.60366	0.31196
1993	1.20650	0.42817	-0.02026	0.34223	0.32217	-0.22442	-0.84038	1.61870	0.17755
1994	-0.27345	-0.40575	0.23932	-0.50378	-0.74978	-0.99852	-1.26740	-0.80859	-0.68312
1995	-0.72334	0.12580	-0.56347	-0.29384	-1.17350	-1.86610	-1.64710	-0.20373	-0.84734

Juv

	1
1983	0.93138
1984	-2.62070
1985	0.15096
1986	-0.92441
1987	0.06190
1988	0.52718
1989	-0.08414
1990	0.23684
1991	0.33066
1992	0.69486
1993	-0.31357
1994	0.60680
1995	0.40227

Table 9c: Residuals from ADAPT analysis.

Table 10a: 4VWX silver hake beginning of year population numbers.

	year								
age	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	906275	660958	861870	1530121	811309	1339186	733661	1795562	783889
2	468951	590781	429576	575812	1009260	539081	849309	479623	1166555
3	217684	267514	338812	267497	343061	598079	324219	463640	264718
4	88644	87624	122783	139841	118438	184619	235553	138525	129667
5	53526	30250	33169	52202	39646	55852	57973	56889	27107
6	17796	18082	8827	12710	10171	17442	21979	12138	15517
7	11983	4095	7963	3336	3810	4102	8260	7319	1393
8	3599	5488	1602	4367	641	1894	1916	3656	3749
9	5818	2012	3313	840	2551	228	1122	1101	2049
10	0	3596	1269	2106	511	1639	145	683	648
age 1+	1774276	1666804	1807915	2586726	2338887	2740483	2233992	2958453	2394644
age 2+	868001	1005846	946045	1056605	1527578	1401297	1500331	1162891	1610755
age 3+	399050	415065	516469	480793	518318	862216	651022	683268	444200
age 4+	181366	147551	177657	213296	175257	264137	326803	219628	179482

	year								
age	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	743769	1082856	629681	615768	702569	831102	643444	1009768	
2	519924	494409	706144	416791	408097	464881	531467	429971	674022
3	609164	297714	262134	305308	185264	213468	244542	345476	259103
4	86552	197625	74514	63301	48308	65626	86509	135434	194694
5	43808	26894	21004	17543	6771	10590	16254	50825	65587
6	7834	12514	2673	4853	2361	1807	2753	9855	29872
7	5584	2777	1210	504	267	600	735	1723	6235
8	655	2042	630	307	111	54	345	478	1108
9	2386	272	454	336	64	48	13	225	287
10	1279	1484	151	272	185	39	30	9	148
age 1+	2019676	2117103	1698444	1424711	1353812	1588176	1526062	1983755	2230908
age 2+	1275907	1034247	1068763	808943	651243	757074	882618	973987	1230908
age 3+	755983	539838	362619	392152	243146	292193	351151	544016	556886
age 4+	146819	242124	100485	86844	57882	78725	106609	198540	297783

Table 10b: 4VWX silver hake beginning of year population biomass (t)

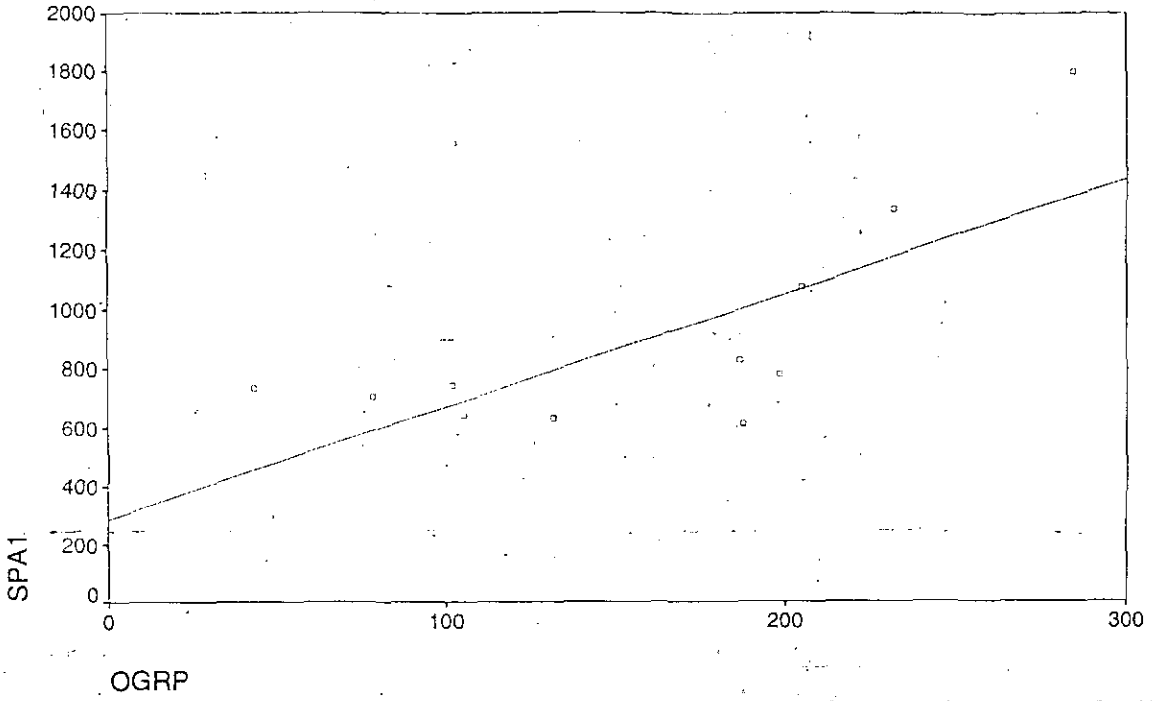
	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	45314	13219	34475	76506	40565	66959	36683	71822	23517
2	56274	64986	34366	57581	90833	53908	84931	47962	93324
3	43537	53503	60986	53499	61751	89712	51875	74182	42355
4	22161	22782	30696	33562	27241	38770	44755	29090	25933
5	15523	9378	10282	15661	11101	13963	13334	13084	6777
6	6051	6148	3266	4576	3458	5581	6154	3156	4190
7	5033	1843	3663	1401	1486	1559	3139	2488	488
8	2231	3403	1121	2315	288	947	939	1682	1537
9	4887	1710	3247	571	1224	125	729	672	1065
10	0	3021	1104	2780	189	672	113	471	441
1+	201010	179992	183206	248451	238137	272197	242652	244611	199626
2+	155696	166772	148732	171945	197572	205238	205969	172788	176110
3+	99422	98766	113261	111584	106550	150657	120925	124355	82345
4+	55886	48284	53379	60865	44988	61618	69163	50644	40431

	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	22313	43314	25187	18473	49180	41555	25738	40391	40000
2	41594	39553	63553	37511	32648	41839	42517	30098	53922
3	91375	47634	41941	48849	29642	29886	29345	41457	33683
4	17310	39525	15648	12660	9662	12469	13841	20315	33098
5	10076	6724	4831	4210	1625	2330	3088	9657	13117
6	2115	3754	802	1310	637	488	688	2365	7468
7	1899	944	436	197	91	198	243	569	2058
8	308	919	252	132	49	18	138	196	421
9	1288	174	241	161	38	30	6	115	155
10	665	1306	159	152	126	31	44	10	164
1+	188943	183847	153049	123657	123697	128844	115649	145172	184086
2+	166630	140533	127862	105183	74517	87289	89911	104781	144086
3+	124371	99674	64150	67520	41744	45419	47350	74673	90000
4+	33661	53346	22368	18823	12227	15564	18049	33226	56481

Table 10c: 4VWX silver hake fishing mortality.

Fishing Mortality	1	2	3	4	5	6	7	8	9	avg age 3-5
1979.00	0.028	0.161	0.510	0.675	0.685	1.069	0.381	0.181	0.081	0.623
1980.00	0.031	0.156	0.379	0.571	0.832	0.420	0.539	0.105	0.061	0.594
1981.00	0.003	0.074	0.485	0.455	0.559	0.573	0.201	0.246	0.053	0.500
1982.00	0.016	0.118	0.415	0.861	1.236	0.805	1.250	0.138	0.097	0.837
1983.00	0.009	0.123	0.220	0.352	0.421	0.508	0.299	0.634	0.043	0.331
1984.00	0.055	0.108	0.532	0.758	0.533	0.347	0.361	0.124	0.055	0.608
1985.00	0.025	0.205	0.450	1.021	1.164	0.700	0.415	0.154	0.096	0.878
1986.00	0.031	0.194	0.874	1.231	0.899	1.765	0.269	0.179	0.130	1.001
1987.00	0.011	0.250	0.718	0.685	0.841	0.622	0.355	0.052	0.072	0.748
1988.00	0.008	0.158	0.726	0.769	0.853	0.637	0.606	0.477	0.075	0.783
1989.00	0.028	0.235	0.985	1.842	1.909	1.936	1.084	1.104	0.190	1.579
1990.00	0.013	0.438	1.021	1.046	1.065	1.267	0.973	0.229	0.113	1.044
1991.00	0.011	0.411	1.444	1.835	1.606	2.501	1.117	1.170	0.198	1.628
1992.00	0.013	0.248	0.638	1.118	0.921	0.970	1.190	0.441	0.100	0.892
1993.00	0.047	0.242	0.503	0.996	0.947	0.499	0.154	1.041	0.079	0.815
1994.00	0.003	0.031	0.191	0.132	0.100	0.068	0.030	0.029	0.009	0.141
1995.00	0.004	0.106	0.173	0.325	0.131	0.058	0.042	0.109	0.016	0.210

Table 11: Regression of 4VWX silver hake juvenile survey O-group index vs age 1 numbers from SPA.



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* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. SPA1

Block Number 1. Method: Enter OGRP

Variable(s) Entered on Step Number 1.. OGRP

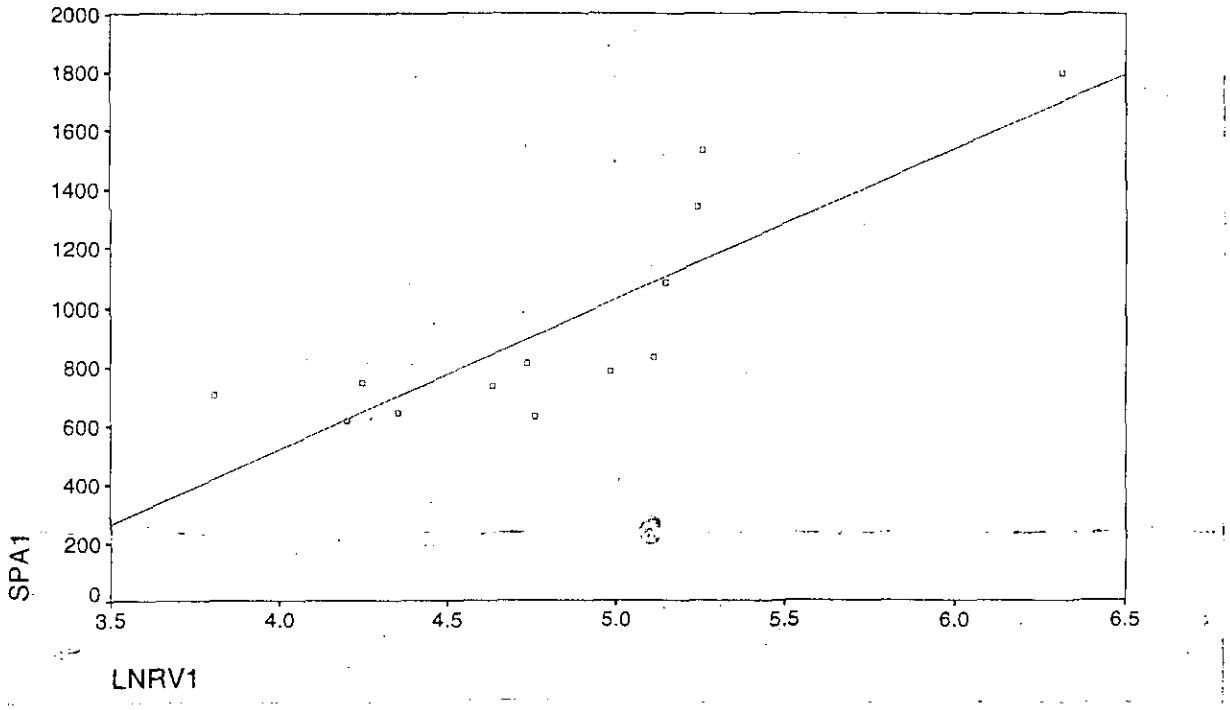
Multiple R	.75953	Analysis of Variance			
R Square	.57689		DF	Sum of Squares	Mean Squar
Adjusted R Square	.52988	Regression	1	783160.53654	783160.5365
Standard Error	252.62789	Residual	9	574387.64527	63820.8494
		F = 12.27123		Signif F = .0067	

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
OGRP	3.841565	1.096640	.759535	3.503	.0067
(Constant)	287.508192	190.788672		1.507	.1661

End Block Number 1 All requested variables entered.

Table 12: Regression of age 1 silver hake from Canadian July RV survey vs SPA age 1.



* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. SPA1

Block Number 1. Method: Enter LNRV1

Variable(s) Entered on Step Number 1.. LNRV1

Multiple R	.84703	Analysis of Variance			
R Square	.71746		DF	Sum of Squares	Mean Square
Adjusted R Square	.69178	Regression	1	1248332.57129	1248332.5712
Standard Error	211.40004	Residual	11	491589.73640	44689.9760
		F = 27.93317	Signif F = .0003		

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
LNRV1	509.207751	96.346272	.847033	5.285	.0003
(Constant)	-1518.383798	469.159168		-3.236	.0079

End Block Number 1 All requested variables entered.

		1995 est	initial est	proportion	avg
age1	1990.00	629681	666070	0.945368	0.953213
	1991.00	615768	576384	1.068329	
	1992.00	702569	487269	1.44185	
	1993.00	831102	1954333	0.425261	
	1994.00	643444	726845	0.885256	
age2	1990.00	706144	1008715	0.700043	0.886113
	1991.00	416791	495471	0.841202	
	1992.00	408097	405363	1.006745	
	1993.00	464881	436947	1.06393	
	1994.00	531467	649201	0.818648	
age3	1990.00	262134	252998	1.036111	0.928376
	1991.00	305308	384425	0.794194	
	1992.00	185264	224693	0.824521	
	1993.00	213468	236955	0.90088	
	1994.00	244542	225141	1.086173	
age4	1990.00	74514	69828	1.067108	0.796627
	1991.00	63301	67955	0.931514	
	1992.00	48308	77905	0.620089	
	1993.00	65626	101318	0.647723	
	1994.00	86509	120704	0.716704	
age5	1990.00	21004	20675	1.015913	0.73608
	1991.00	17543	19069	0.919975	
	1992.00	6771	11512	0.588169	
	1993.00	10590	17612	0.601295	
	1994.00	16254	29284	0.555047	
age6	1990.00	2673	3408	0.784331	0.692943
	1991.00	4853	6349	0.764372	
	1992.00	2361	4306	0.548305	
	1993.00	1807	2680	0.674254	
	1994.00	2753	3970	0.693451	

Table 13: Comparison of 1995 estimates of population numbers to initial estimates from retrospective analysis, age by age.

POPULATION NUMBERS 15/ 6/96

	1995	1996	1997
1	910000	1280000	800000
2	381011	607147	853125
3	320731	226299	378949
4	107890	178125	123156
5	37411	47208	89748
6	6829	20888	25545
7	1194	4207	11597
8	331	753	2487
9	156	189	433
1+	1765553	2364814	2285039
2+	855553	1084814	1485039
3+	474542	477667	631915
4+	153811	251369	252966

POPULATION BIOMASS (AVERAGE) 15/ 6/96

	1995	1996	1997
1	42658.12	59973.66	37339.03
2	30587.73	49864.04	66827.71
3	33947.00	23734.23	34817.90
4	12994.61	22820.06	13220.49
5	5953.76	7407.68	12295.77
6	1553.40	4531.51	4913.29
7	373.15	1276.11	3241.14
8	99.52	227.28	679.28
9	97.41	117.88	266.23
1+	128264.71	169952.45	173600.84
2+	85606.59	109978.79	136261.81
3+	55018.86	60114.75	69434.11
4+	21071.85	36380.52	34616.21

CATCH NUMBERS 15/ 6/96

	1995	1996	1997
1	3498	6007	9171
2	35925	34551	113542
3	45615	35330	127085
4	31316	36806	52284
5	5183	7553	30739
6	457	2975	7909
7	58	411	2560
8	41	89	653
9	3	4	19
1+	122096	123726	343964
2+	118598	117719	334793
3+	82673	83167	221251
4+	37058	47837	94166

Table 14: Results of projection at $F_{0.1}$, for 4VWX silver hake.

CATCH BIOMASS 15/ 6/96

	1995	1996	1997
1	199	342	523
2	3700	3559	11695
3	6386	4946	17792
4	5543	6515	9254
5	1088	1586	6455
6	131	854	2270
7	23	160	998
8	16	35	257
9	2	3	15
1+	17089	18000	49259
2+	16890	17658	48736
3+	13190	14099	37041
4+	6804	9153	19250

FISHING MORTALITY 15/ 6/96

	1995	1996	1997
1	0.005	0.006	0.014
2	0.121	0.071	0.175
3	0.188	0.208	0.511
4	0.427	0.285	0.700
5	0.183	0.214	0.525
6	0.084	0.188	0.462
7	0.061	0.126	0.308
8	0.162	0.154	0.378
9	0.024	0.023	0.056
1+	0.093	0.069	0.220

WEIGHTS AT THE BEGINNING OF THE YEAR 15/ 6/96

	1994	1995	1996	1997	1998
1	0.04	0.04	0.04	0.04	0.04
2	0.09	0.08	0.08	0.08	0.08
3	0.12	0.12	0.12	0.12	0.12
4	0.16	0.16	0.16	0.16	0.16
5	0.18	0.19	0.19	0.19	0.19
6	0.25	0.25	0.25	0.25	0.25
7	0.39	0.33	0.33	0.33	0.33
8	0.28	0.39	0.39	0.39	0.39
9	0.55	0.55	0.55	0.55	0.55
10	1.07	1.07	1.07	1.07	1.07

Table 14 (cont): Results of projection at $F_{0.1}$, for 4VWX silver hake.

POPULATION BIOMASS AT BEGINNING OF YEAR 15/ 6/96

	1995	1996	1997
1	38586	54275	33922
2	29194	46521	65369
3	38514	27175	45505
4	16984	28040	19387
5	7213	9101	17303
6	1677	5128	6271
7	399	1407	3880
8	130	295	974
9	86	104	237
1+	132782	172046	192848

DISTRIBUTION OF GROWTH OVER AGES (PERCENT) 15/ 6/96

	1995	1996	1997
1	47.1	48.5	30.9
2	26.0	30.8	43.0
3	17.7	9.1	14.3
4	5.3	6.7	4.3
5	2.6	2.4	3.9
6	0.9	1.9	2.2
7	0.1	0.3	0.9
8	0.1	0.1	0.3
9	0.1	0.1	0.2

PRODUCTION 15/ 6/96

SOURCE	1995	1996	1997
RECRUITMENT BIOMASS	38586	54275	33922
GROWTH	53493	72993	71410
TOTAL PRODUCTION	92079	127269	105332
LOSS THROUGH FISHING	17089	18000	49259
SURPLUS PRODUCTION	40773	59288	35892
NET PRODUCTION	23684	41288	_13367

PRODUCTION/BIOMASS RATIO 15/ 6/96

1995	1996	1997
0.72	0.75	0.61

SUMMARY OF PROJECTIONS 15/ 6/96

YEAR	1995	1996	1997
POPULATION NUMBERS	1765553.00	2364814.14	2285039.46
POPULATION BIOMASS	128264.71	169952.45	173600.84
CATCH	17089.31	18000.00	49259.06
F OR QUOTA	17089.31	18000.00	0.70

AGE GROUPS CONSIDERED:1+

Table 14 (cont): Results of projection at $F_{0.1}$, for 4VWX silver hake.

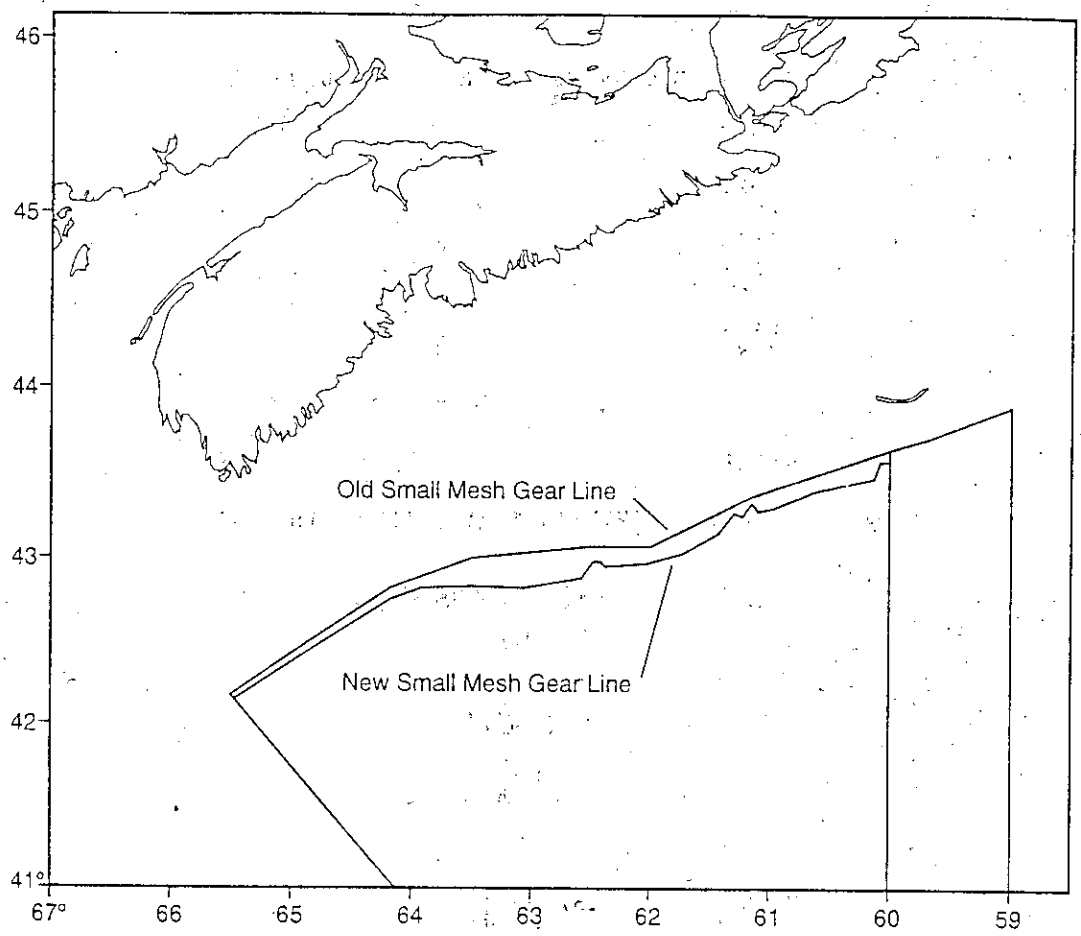


Figure 1: The old and new Small Mesh Gear Line (SMGL).

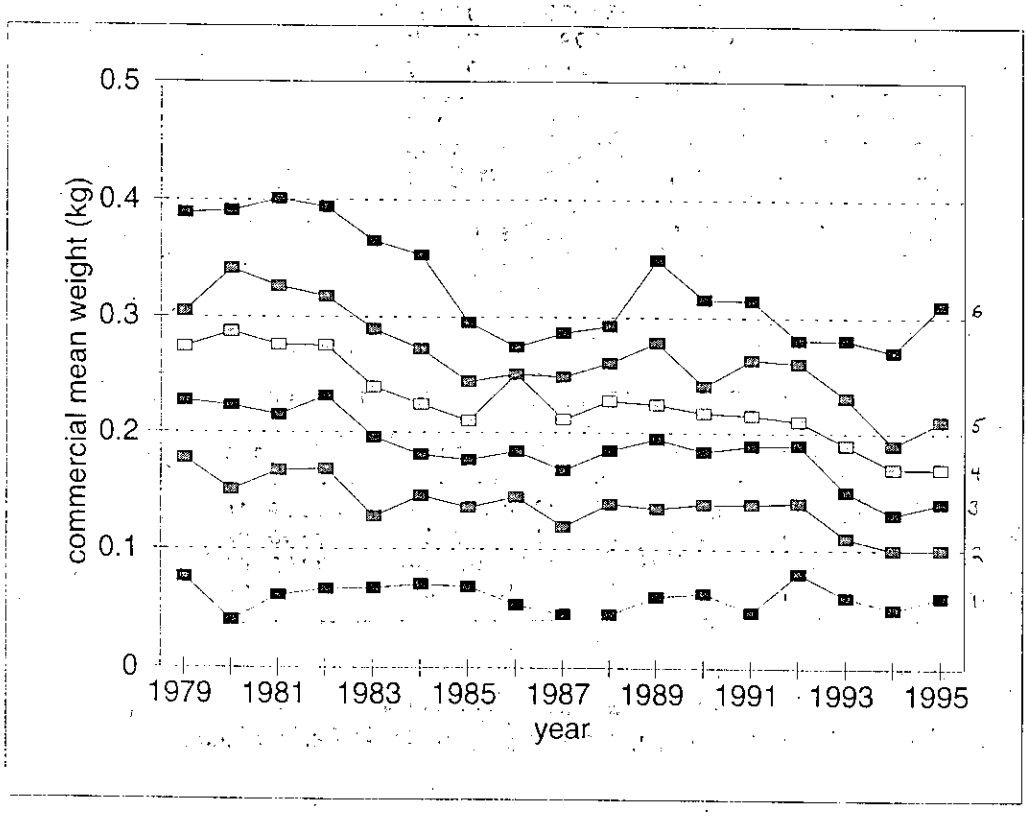


Figure 2: Mean weight (kg) at age (1-6) from the commercial fishery for 4VWX silver hake.

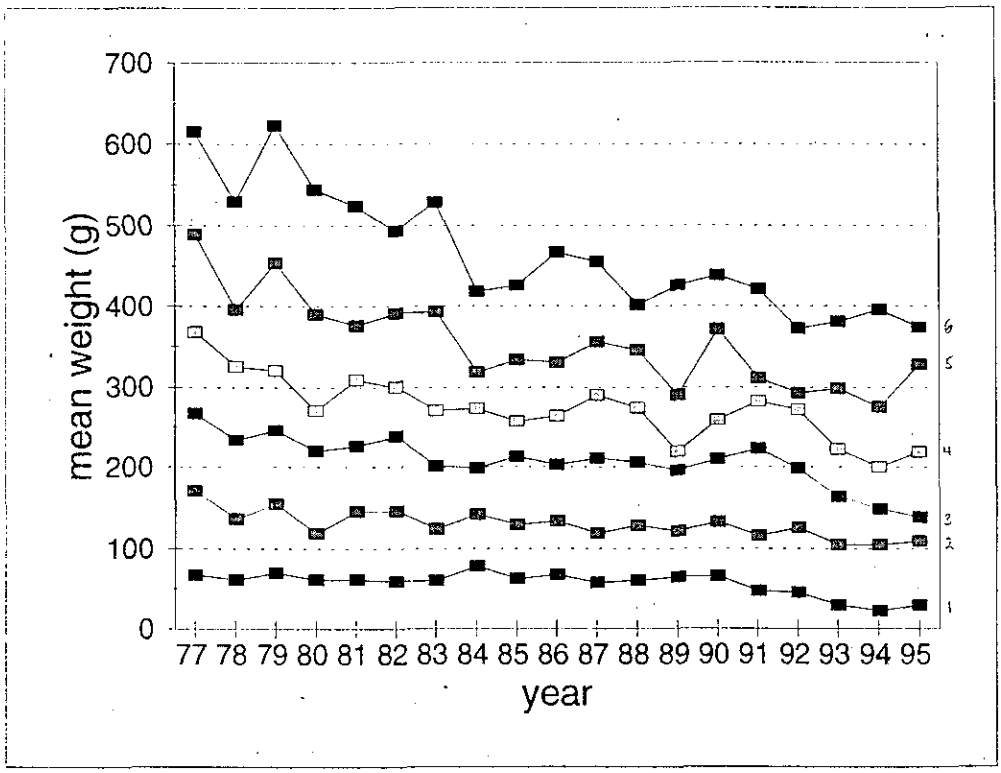


Figure 3 : Mean weight (g) at age (1-6) from the Canadian July RV survey.

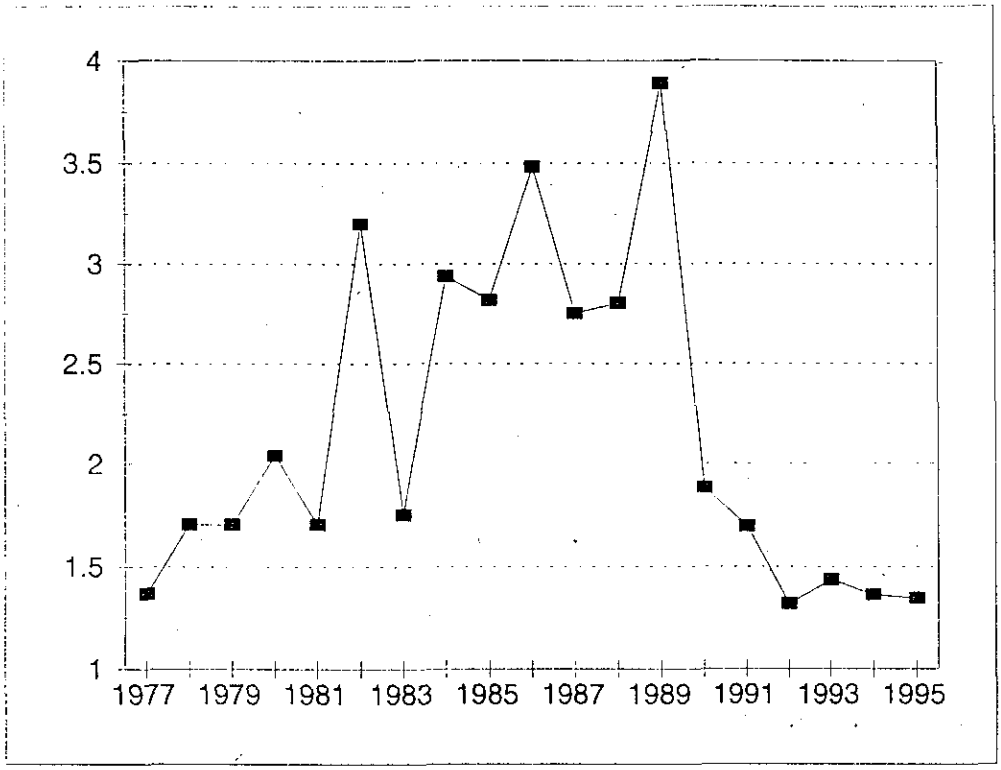


Figure 4: Non-standardized commercial catch rates for 4VWX silver hake, based on Canadian observer data 1977-95.

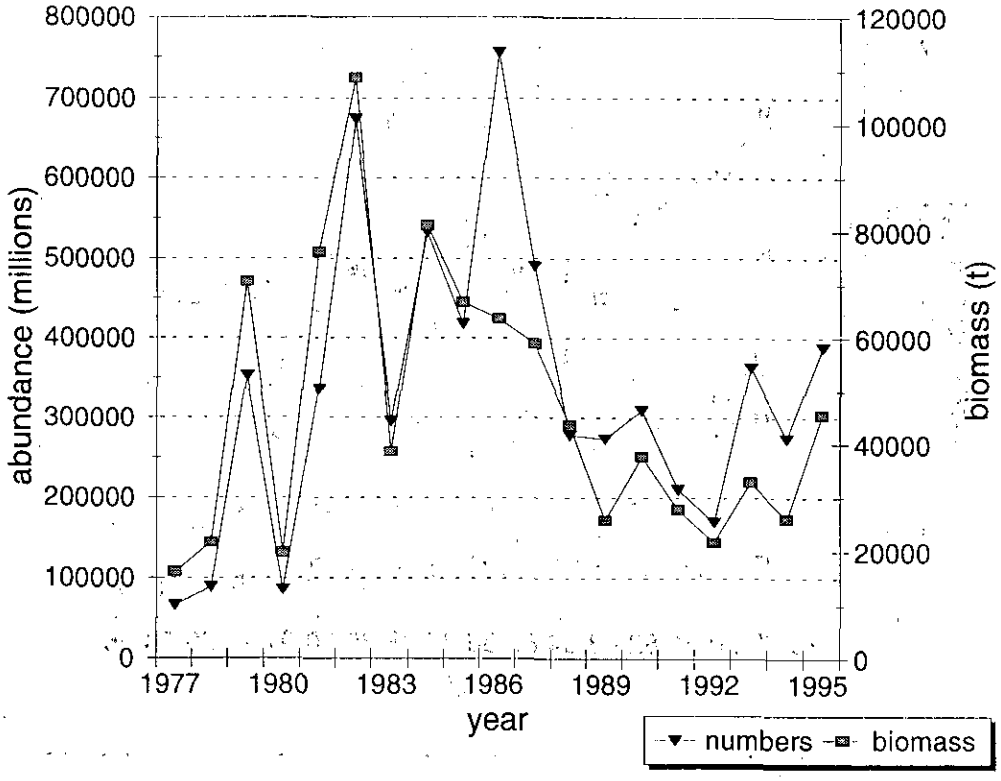


Figure 5: 4VWX silver hake Canadian July survey estimates of age 1+ numbers and biomass.

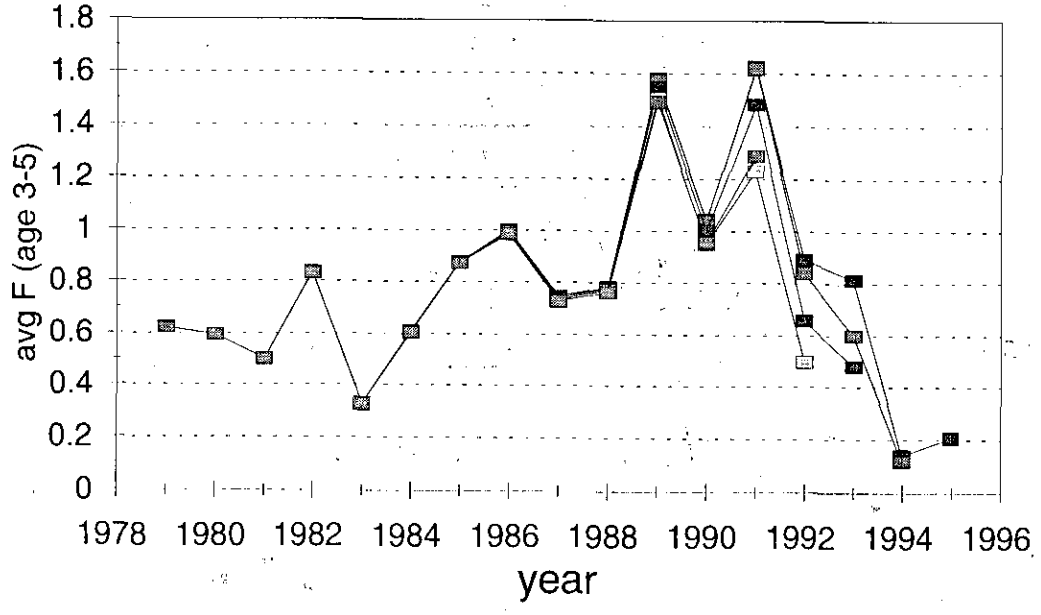
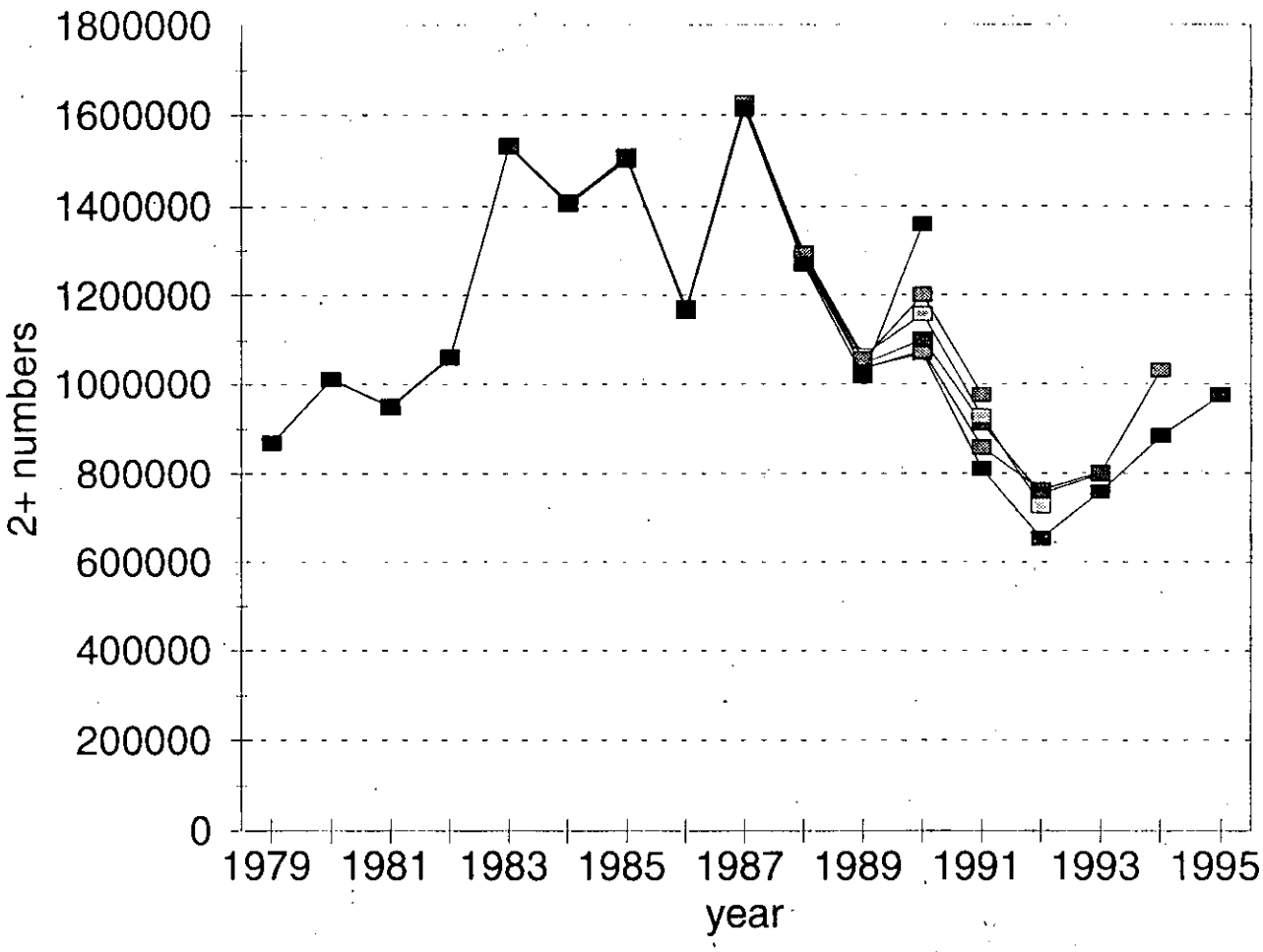


Figure 6: Results of retrospective analysis for average F, ages 3-5, derived from ADAPT.



year	initial estimate	converged estimate	proportion
1994	1,029,339	882,648	0.86
1993	796,863	757,113	0.95
1992	725,275	651,428	0.90
1991	975,593	809,215	0.83
1990	1,358,445	1,068,914	0.79

Figure 7: Comparison of 2+ numbers from retrospective analysis for 4VWX silver hake.

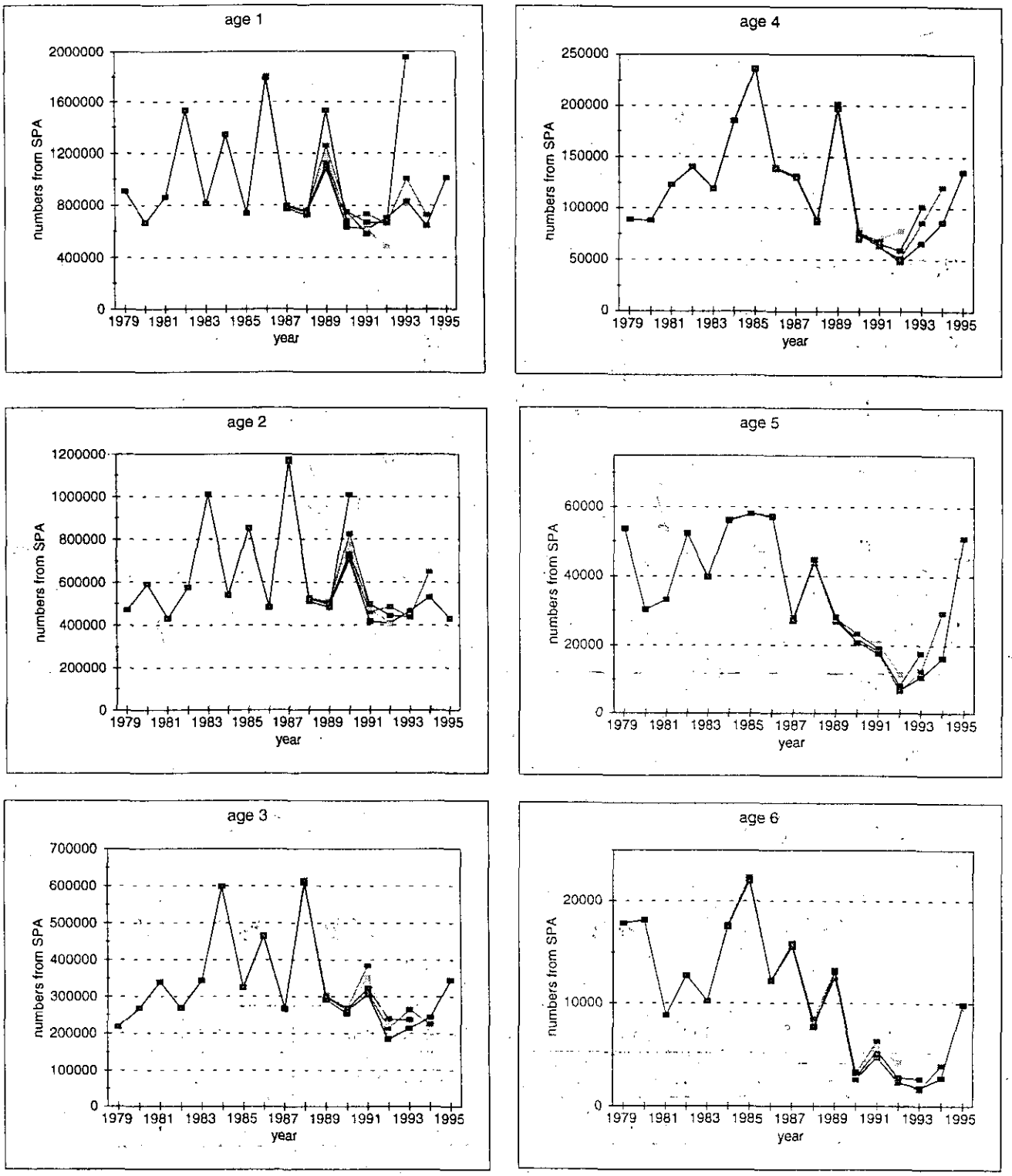


Figure 9: Retrospective analysis of population numbers for 4VWX silver hake; age by age comparisons.